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THE POST-JURASSIC IGNEOUS ROCKS OF SOUTHWESTERN NEVADA[1]

SYDNEY H. BALL

INTRODUCTION

Three mighty periods of igneous activity mark the geological history of southwestern Nevada and eastern California. The latest of these, the Tertiary, has been ably treated by Spurr[2] while concerning the earliest, the pre-Cambrian, we know little. It is the purpose of this article to describe briefly the period of igneous activity beginning in post-Jurassic time and ceasing long prior to the Eocene.

During the field season of 1905 the writer made a reconnaissance of some 8,500 square miles in southwestern Nevada and eastern California for the United States Geological Survey.[3] This area lies between 36° 30′ and 38° North latitude and 117° 30′ and 116° West longitude (see Fig. 1).

GENERAL STATEMENT

The earliest of the post-Jurassic igneous rocks recognized in the area are the granular siliceous intrusive rocks; next came the intrusion of quartz-monzonite porphyry, poor in ferromagnesian minerals, while the youngest of the pre-Tertiary rocks are diorite and diorite-porphyry.

DISTRIBUTION

The post-Jurassic igneous rocks are widely distributed over the area under consideration although they cover larger expanses in its western portion, and are the predominant formation from longitude 117° 30′ westward to the Sierra Nevada. The Tertiary lavas and sedimentary rocks and the Pleistocene and Recent terrestrial deposits cover vast stretches so that a cursory examination of a geological map of Nevada gives but little idea of the importance of

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[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] J. E. Spurr, *Journal of Geology*, Vol. VIII, pp. 621–46.

[3] See *Bull. U. S. Geological Survey No. 308*.

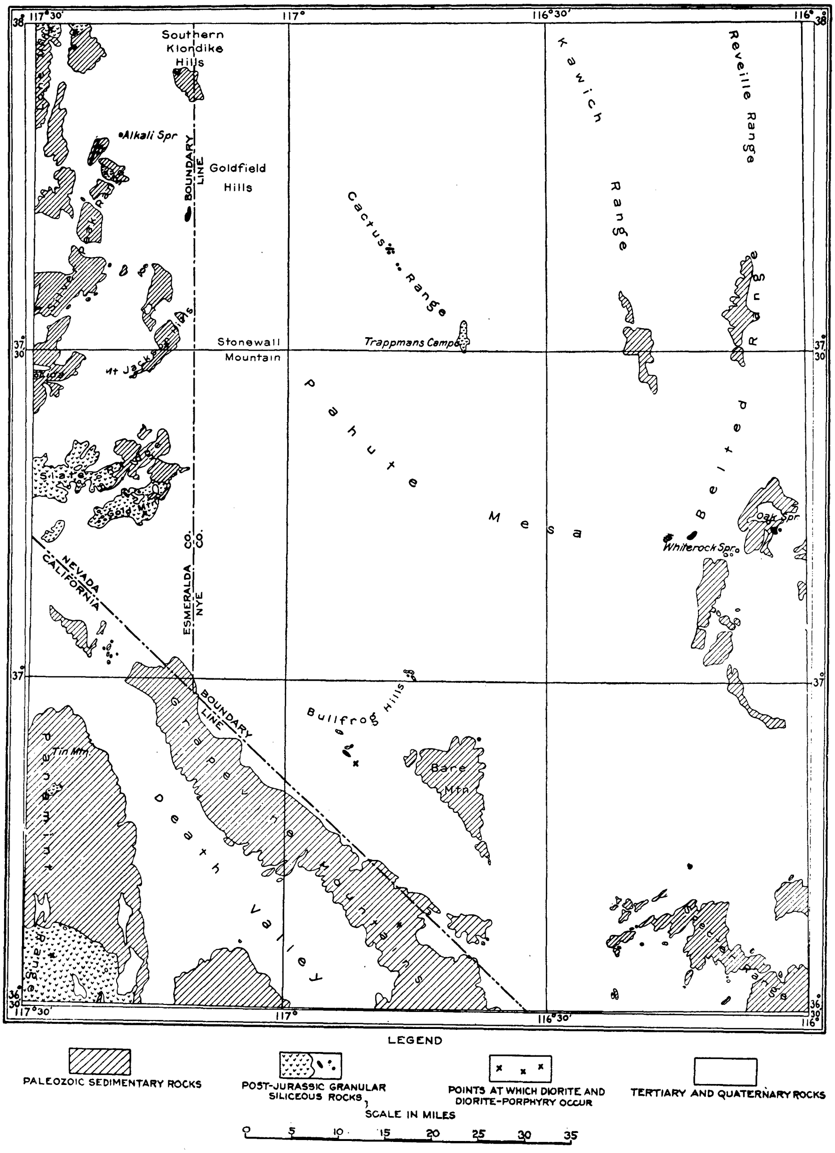
117°30′
117°
116°30′
116°
38°
37° 30′
37°
36° 30′
Southern Klondike Hills
Alkali Spr
Goldfield Hills
BOUNDARY LINE
Stonewall Mountain
Mt Jackson
Slate Ridge
Gold Mtn
ESMERALDA CO.
NYE CO.
NEVADA
CALIFORNIA
Cactus Range
Trappmans Camp
Kawich Range
Reveille Range
Pahute Mesa
Belted Range
Oak Spr
Whiterock Spr
Bullfrog Hills
Bare Mtn
Tin Mtn
Panamint Range
Grapevine Mountains
Death Valley
BOUNDARY LINE
LEGEND
PALEOZOIC SEDIMENTARY ROCKS
POST-JURASSIC GRANULAR SILICEOUS ROCKS
POINTS AT WHICH DIORITE AND DIORITE-PORPHYRY OCCUR
TERTIARY AND QUATERNARY ROCKS
SCALE IN MILES
0 5 10 15 20 25 30 35

FIG. 1

the post-Jurassic igneous intrusives. But when we consider only the region at present covered by pre-Tertiary formations we find that the widely distributed masses of post-Jurassic igneous rocks form approximately one-sixth of this territory. Moreover, at many places where Tertiary lavas mask the older formations, fragments of pre-Tertiary igneous rocks are included in the lavas, thus showing the presence of these older rocks on the sides of the conduit through which the molten Tertiary rock welled.

THE GRANULAR SILICEOUS SERIES

GENERAL STATEMENT

This series is composed of four rocks which were intruded in the following order; monzonite and quartz-monzonite porphyry; granular rocks, including granite, quartz-monzonite, and soda syenite; aplites and pegmatites. These rocks in each separate batholith solidified successively from a single magma in the reverse order of their acidity.

MONZONITE AND QUARTZ-MONZONITE PORPHYRY

The granular igneous rocks of the Belted and Panamint ranges, of Pahute Mesa, and of Gold Mountain Ridge, contain fragments of fine-grained gray monzonitic rocks. That of Gold Mountain is a quartz-monzonite porphyry in which the ferromagnesian mineral is biotite. A specimen from the Belted Range is a basic hornblende-biotite-monzonite. These monzonites, while somewhat older than the granular siliceous rocks in which they occur, are massive and are believed to be a somewhat earlier crystallization of the magma from which the more siliceous rocks afterward solidified.

GRANITES, QUARTZ-MONZONITE AND SODA-SYENITE

Petrographic character.—These rocks range on the one hand from alaskite through muscovite-, muscovite-biotite-, and biotite-granite to a quartz-monzonite approaching granodiorite, and on the other hand from normal granite through soda-rich granite to soda-syenite. Most of these rocks grade into corresponding porphyries. The lithologic character of the rocks of most of the areas shown on the map (see Fig. 1) is usually rather constant, although in the Gold Mountain Ridge granite-porphyry grades into hornblende-bearing quartz-monzonite porphyry in a distance of only ten feet.

Many of these rocks are characterized by large porphyritic feldspars. The granite at Oak Spring in the Belted Range contains phenocrysts of feldspar, quartz, and biotite which reach maximum lengths of 4 inches, ½ inch, and 1 inch respectively. The feldspar phenocrysts are locally sufficiently abundant to form one-third of the rock mass. The microscopic character of the granular siliceous rocks are tabulated in Table I, and those of the corresponding porphyries in Table II.

From the east to the west edge of the area under consideration the rocks in the main become progressively less siliceous and the quartz-monzonite of the Panamint Range approaches in composition the granodiorite of the Sierra Nevada. In a broad way then the magmas in the various centers of igneous activity were less and less siliceous from meridian 116 west to the Sierra Nevada. There is also a slight increase in the soda content of the rocks from the eastern border of the area to the western.

The soda-syenite and soda-syenite porphyry which form a small mass intrusive in Pennsylvanian limestone 11½ miles southeast of Tin Mountain (Panamint Range) are worthy of more detailed description. The soda-syenite is characterized by abrupt and great changes in granularity and in the relative abundance of the constituent minerals. The most common type is a coarse to medium-grained gray rock composed of predominant gray with some pink feldspar, subordinate greenish-black amphibole or pyroxene, and biotite. Many of the feldspars have good crystal outlines and in the more porphyritic facies the abundant feldspar laths which have lengths of 1½ inches are aligned in flow orientation. The rock, next to the limestone, is very fine grained. Epidote has developed at the expense of the ferromagnesian minerals in all facies. Under the microscope this rock proves to be a soda-syenite or nordmarkite of uneven hypidiomorphic granular texture. Alkali feldspars are the predominant constituents and include the species orthoclase, microperthite, and anorthoclase. With these is a little oligoclase. The alkali feldspars form rude tabular crystals, many of which are twinned according to the Carlsbad law. Augite sometimes occurs in columns, or anhedra of augite, green hornblende, quartz, biotite, and yellowish-brown garnet may lie between these tabular forms. The augite shows characters approaching aegirite-augite. The accessory minerals are titanite, magnetite, apatite, and fluorite. Fluorite flecks the alkali feldspar and was probably introduced by magmatic gases.

The soda-syenite is cut by dikes of a compact greenish-gray aplite. Pink feldspar is associated with the gray feldspar, and some veins are composed wholly of pink feldspar with pyroxene. Under the microscope the aplite has a very uneven-grained, allotriomorphic texture. The feldspars include microperthite, orthoclase, and some anorthoclase; a little quartz is also present. Although the rock is not rich in ferromagnesian minerals, there are many small grains and partial crystals of aegirite-augite, which show the usual zonal structure, with deeper green bands on the border. Irregular grains of a light-yellow garnet are rather abundant and titanite and apatite are accessories. Fluorite occurs in small blebs, surrounded by a mesh of sericite shreds, which were probably formed by the same gases that deposited the fluorite. Calcite is also present and its contacts with other minerals are so sharp that it was probably deposited in miarolitic openings. The contact between the aplite and the syenite is in some cases sharp, in others gradational. In one instance a dike of syenite porphyry is faulted along an aplitic dike, but there is little doubt that the two are genetically related. Narrow pegmatitic dikes, the feldspar and pyroxene of which reach a diameter of 1 inch, also occur.

The soda-syenite intrudes Pennsylvanian limestone and has suffered the same deformation as the quartz-monzonite which lies to the south of it (No. 11, Table I). Phases of the pegmatite of the monzonite closely resemble the soda-syenite in mineral composition and from this fact and the proximity of the two masses the soda-syenite is believed to be a later differentiation of the monzonitic magma. At places the pegmatite of the monzonite has a border composed of almost pure augite with a median band of feldspar. The boundary planes are rather distinct although individual crystals extend from the monzonite into the basic bands and from these into the acidic center. The more siliceous portion shows under the microscope the composition of a soda-syenite, and consists of orthoclase, anorthoclase, augite, hornblende, oligoclase, quartz, titanite, magnetite, apatite, and zircon. Titanite occurs both in well-crystallized wedges

TABLE I

Granular Siliceous Rocks

Name and Place	Alaskite	Muscovite-granite	Biotite-muscovite-granite	Biotite-granite	Biotite-granite	Biotite-granite	Bi
	Bullfrog	Southern Klondike	Trapmann's Camp, Pahute Mesa	Slate Ridge	Gold Mountain, West End	White Rock Spring, Pahute Mesa	Sil
Texture	Allotriomorphic	Allotriomorphic	Allotriomorphic	Allotriomorphic	Hypidiomorphic	Hypidiomorphic with orthoclase poikilitic	Hy
Granularity	Medium	Fine	Fine to medium	Coarse	Fine	Coarse	Me
Quartz	Essential	Predominant	Essential	Essential	Predominant	Essential	Es
Orthoclase	Essential	Essential	Predominant	Predominant	Essential	Predominant	Pr
Micropegmatite	Present						
Microperthitic intergrowth						Present	Pr
Microcline	Present	Present					
Oligoclase		Present	Essential		Essential	Essential	Es
Muscovite	Secondary	Essential	A little, both original and secondary		x		
Biotite	Present		Essential	Essential	Essential	Not abundant	Es
Hornblende							
Augite							
Titanite					x	x	
Apatite	x[1]				x	x	
Zircon	x		x	x	x	x	
Magnetite	x			x	x	x	
Allanite							

[1] Symbol x indicates that the mineral is present as an accessory.

TABLE II

Porphyritic Rocks of Granular Siliceous Serie

Name and place	Granite Porphyry	Granite Porphyry	Granite Porphyry	Granite Porphyry	Granite Porp
	Silver Peak	Panamint	Silver Peak	Grapevine Mountains	Kawich
Proportions of phenocrysts and ground-mass	Phenocrysts= Ground-mass	Ground-mass > Phenocrysts	Ground-mass > Phenocrysts	Phenocrysts= Ground-mass	Phenocrysts= Ground-ma
Texture of ground-mass	Allotriomorphic with areas micropegmatitic	Allotriomorphic with areas micropegmatitic	Hypidiomorphic with micro-pegmatitic areas	Hypidiomorphic	Hypidiomorp
Quartz of ground-mass	Essential	Essential	Predominant	Predominant	Essential
Orthoclase of ground-mass	Essential	Microcline and orthoclase predominant	Essential	Essential	Essential
Plagioclase of ground-mass		Oligoclase	Present	Present	Present
Other constituents of ground-mass		Biotite			
Quartz phenocrysts	Predominant	Predominant	Essential	Essential	Essential
Orthoclase phenocrysts	Essential	Essential	Essential	Predominant	Predominant
Plagioclase phenocrysts	Present, Oligoclase-albite	Present	Present	Sparse	Present
Microperthite	Orthoclase phenocrysts microperthitic		Orthoclase phenocrysts microperthitic	Orthoclase phenocrysts microperthitic	
Biotite phenocrysts	Rare	Rare	Rare	Rare	Present
Hornblende phenocrysts					
Accessory minerals		Magnetite, Titanite, Apatite	Magnetite	Magnetite, Zircon, Apatite, Titanite	Magnetite, Zi con, Apatit
Micropegmatite of quartz and orthoclase	Ground-mass, also coronae around phenocrysts; also phenocrysts	Ground-mass	Ground-mass		

TABLE I

GRANULAR SILICEOUS ROCKS

:	Biotite-granite	Biotite-granite	Biotite-granite	Biotite-granite	Biotite-granite	Biotite-hornblende-granite	Quartz-monzonite
	Gold Mountain, West End	White Rock Spring, Pahute Mesa	Silver Peak	Gold Mountain Ridge	Lone Mountain	Belted Range	Panamint Mountains
ic	Hypidiomorphic	Hypidiomorphic with orthoclase poikilitic	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic, porphyritic	Hypidiomorphic
	Fine	Coarse	Medium	Coarse	Medium to coarse	Coarse	Medium
	Predominant	Essential	Essential	Essential	Not abundant	Essential	Present
	Essential	Predominant	Predominant	Essential	Predominant	Predominant	Essential
					Present		Present
		Present	Present	Present			
				Present	Essential	Present	
	Essential	Essential	Essential	Essential	Present	Essential	Predominant
	x						
	Essential	Not abundant	Essential	Essential		Essential	Essential
						Essential	Essential
							Present
	x	x			x		x
	x	x			x	x	x
	x	x	x		x	x	
	x	x	x	x	x		x
					x		

TABLE II

ITIC ROCKS OF GRANULAR SILICEOUS SERIES

orphyry	Granite Porphyry	Granite Porphyry	Granite Porphyry	Granite Porphyry	Quartz-monzonite Porphyry	Quartz-monzonite Porphyry
k	Grapevine Mountains	Kawich	Cactus Hills	Gold Mountain Ridge	Gold Mountain Ridge	Silver Peak Range
ass > ysts	Phenocrysts= Ground-mass	Phenocrysts= Ground-mass	Phenocrysts > Ground-mass	Phenocrysts > Ground-mass	Phenocrysts > Ground-mass	Phenocrysts > Ground-mass
orphic cro-peg- areas	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic	Hypidiomorphic	Allotriomorphic	Hypidiomorphic with poikilitic areas, quartz enclosing others
int	Predominant	Essential	Essential	Essential	Predominant	Present
	Essential	Essential	Essential	Predominant	Essential	Essential
	Present	Present	Present	Present	Present	Predominant
			Biotite	Biotite essential	Biotite and Hornblende essential	
	Essential	Essential	Subordinate	Essential		
	Predominant	Predominant	Predominant	Microperthite and microcline predominant	Orthoclase and mi-microcline predominant	Essential
	Sparse	Present	Sparse		Essential	Predominant
pheno- icro- :	Orthoclase phenocrysts microperthitic			Phenocrysts		
	Rare	Present	Essential	Essential		Essential
						Present
	Magnetite, Zircon, Apatite, Titanite	Magnetite, Zircon, Apatite	Magnetite, Zircon, Apatite	Magnetite, Apatite, Titanite	Magnetite, Titanite, Zircon, Magnetite	Magnetite, Apatite, Zircon, Allanite
ass				In ground-mass		

which were among the first to solidify from the magma and also in anhedra between the tabular feldspars, this titanite being among the last minerals to separate from the magma. In other phases of the pegmatite partial crystals of ferromagnesian minerals are inclosed in a coarse crystalline aggregate of feldspar. Microscopic examination shows that orthoclase and microperthite are so predominant over plagioclase in this rock that it has the composition of a syenite. A little quartz is present and the ferromagnesian minerals include augite, olivine, brown hornblende, and biotite. Augite in unusually large crystals and magnetite in grains also occur. In this rock there are associated the two minerals, quartz and olivine, which at one time were believed never to occur together.

Weathering.—Southwestern Nevada has an arid climate and consequently the granitoid rocks weather into a soil composed of fragments of the constituent minerals which are practically fresh. This mechanical disintegration, largely dependent upon stresses due to changes of temperature, is so rapid that broad basins of granitic soil extend up into the hills. Through these detrital embayments low domical outcrops of granite protrude and it is only in the highest peaks that exposures are conspicuous.

Age.—From the uniform amount of mashing which these rocks have suffered and from the similarity in the geological history of the various ranges, it is evident that all of these rocks are approximately of the same age. They intrude the Paleozoic rocks as batholiths, stocks, sheets, and dikes, where the contacts can be observed, and fragments of them are included in Tertiary lavas. The youngest Paleozoic rocks in the area are of Pennsylvanian age and these are intruded by granular igneous rocks in the Belted and Panamint ranges. The earliest lavas occur in the Stonewall Mountains and these rocks, which are of very late Cretaceous or early Eocene age,[1] contain fragments of granite. The granular rocks are, therefore, of post-Carboniferous and pre-Tertiary age. Spurr[2] found rocks of similar composition cutting Triassic strata in the Pilot and Excelsior

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[1] Sydney H. Ball, *Bulletin 308 U. S. Geological Survey*, p. 33.

[2] J. E. Spurr, *Bulletin 208, U. S. Geological Survey*, pp. 103, 109.

(Nevada) ranges, and Louderback[1] states that granite intrudes Triassic rocks in the Humbolt (Nevada) range.

Later students of Nevada geology believe with King[2] that the mountain ranges of the western part of the state and the Sierra Nevada were formed simultaneously at the close of the Jurassic. The granite intrusion was probably a relatively late event in this period of deformation, an inference supported by the relatively unmashed condition of the granite. The erosion, prior to the outpouring of the earliest Tertiary lavas, of the thick covering of superincumbent rocks, which must have been present in order to produce the granular texture of the plutonic rocks also points to the post-Jurassic or very early Cretaceous age of the igneous rocks. Such an age determination is in harmony with that of the granodiorite of the Sierra Nevada. That mountain system and the ranges of western Nevada have had a closely parallel history.

While these granular siliceous rocks are thus believed to have been contemporaneous in a broad way, their consolidation unquestionably occurred at slightly different times. This is indicated not alone from the relation between the pegmatite of the quartz-monzonite and the soda-syenite of the Panamint Range, but also from the wide lithologic variety in the granular rocks of the Silver Peak Range (see column 7, Table I, and columns 1, 2, 6, and 7, Table II). There indeed the granular rocks may have solidified from wholly separate magmatic basins.

The conclusion as to the post-Jurassic age of these rocks is in accord with that of Spurr, for the granites of Silver Peak[3] and Goldfield,[4] Nevada, and that of Louderback[5] for similar rocks in the Humbolt Range, Nevada.

APLITE

The granitoid rocks of most of the areas are cut by narrow dikes of aplite, a fine-grained rock of white or pink color. In composition the aplite and granitoid rocks differ in the relative proportions rather than in the kind of minerals present. The aplites are more siliceous than the older granitoid rocks, those of the granites usually having alaskitic affinities and those of the quartz-monzonite, granitic affinities. Upon weathering the aplites protrude from the surface of the granitoid rocks.

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[1] George D. Louderback, *Bulletin Geological Society of America,* Vol. XV, p. 318.

[2] Clarence King, *U. S. Geological Explor. 40th Parallel,* Vol. I, 1878, p. 759.

[3] J. E. Spurr, *Bi-monthly Bull. Amer. Inst. of Min. Engrs.,* 1905, No. 5, p. 955; also Professional Paper No. 55, *U. S. Geological Survey,* pp. 25, 26.

[4] J. E. Spurr, Bull. 260, *U. S. Geological Survey,* 1905, p. 133.

[5] G. D. Louderback, *Bull. Geol. Soc. of Amer.,* Vol. XV, 1904, p. 336.

PEGMATITE

Pegmatite is usually associated with the granitoid rocks and is the only representative of the granular siliceous series at Bare Mountain, and is the predominant intrusive of the Bullfrog Hills. At most places it cuts the granitoid rocks with sharp contacts, and normally the intrusion of aplite intervened between that of granite and of pegmatite, although graduations from pegmatite to granite also occur. At one place in the Gold Mountain Ridge an aplite dike passes along its strike into a dike with narrow aplitic border and broad pegmatitic center.

The pegmatite usually occurs in well-defined dikes but throughout the more easterly of the two granite masses in the Pahute Mesa ellipsoidal masses of coarse quartz-feldspar-pegmatite are inclosed in the granite. The contact between the two rocks is at some places sharp, at others gradational. The ellipsoidal form and the absence of apparent channels from one mass to another in the plane of observation suggest that the pegmatite formed in place from the residual fluids of the granitic magma.

Chemically the pegmatites are more acid than their granitoid associates although in the Panamint Range the pegmatite of the quartz-monzonite has also undergone a considerable enrichment in soda. In texture the pegmatites are either coarse, irregular, granular aggregates or the intimate intergrowth commonly called graphic granite. The latter rock in the Gold Mountain Ridge is a transition phase between granite and coarsely granular pegmatite.

The pegmatites of southwestern Nevada contain but few rare minerals. Pyrite occurs as an original constituent of the pegmatite in the Belted Range and in the Bullfrog Hills. At the former locality it is reported to carry values in gold and silver and in 1905 was being prospected. The gradation from either a muscovite- or biotite-pegmatite to quartz veins is seen in most of the larger granite areas.

At the Bullfrog-George prospect in the Slate Ridge molybdenite, molybdite, and fluorite occur in a pegmatitic quartz vein. Molybdenite is present as metallic tablets and irregular scales of steel-gray color which lie between or are surrounded by the interlocking quartz crystals of the vein. It evidently solidified from the magmatic waters contemporaneously with the quartz. Its alteration product, a bright-yellow mineral in minute crystals and tufted aggregates, was determined by W. T. Schaller to be molybdite. Fluorite, which occurs in fractures in the quartz and also lines its vugs, is evidently somewhat younger than quartz and presumably was deposited by gases in the expiring stages of volcanism.

In the Bullfrog Hills there is some evidence of two separate intrusions of pegmatitic material. The older pegmatite is a feldspar-muscovite-quartz rock which is cut by a very siliceous pegmatite dike of almost pure quartz. It is probable then that from the residium of the granite magma a coarse-grained rock with the composition of a granite first separated and solidified and at a later period a more quartzose rock was deposited from the residual liquid in fractures in the older pegmatite.

QUARTZ-MONZONITE PORPHYRY

Dikes and sheets of quartz-monzonite porphyry, poor in ferromagnesian minerals, intrude Paleozoic rocks and granite of the Silver Peak Range and Slate Ridge. This rock near Lida is apparently cut by the diorite porphyry described below.

The monzonite porphyry is a dense white or greenish-white rock with abundant medium-sized phenocrysts, which however are subordinate in bulk to the ground-mass. They consist of whitish feldspars, some striated and others unstriated, silvery mica, and a few quartz crystals. The central portions of the dikes and sheets are more coarsely crystalline than the borders and in instances approach a granitoid texture.

Microscopic examination proves the medium-grained micrographitic ground mass to consist of orthoclase, microperthite, and anorthoclase grains, plagioclase laths, and a few quartz anhedra. In some thin sections the alkali feldspars poikilitically inclose the other minerals and in others quartz and orthoclase are in graphic intergrowth.

The phenocrysts of orthoclase and microperthite predominate over those of plagioclase (oligoclase and oligoclase-andesine). Altered biotite phenocrysts are constantly present while quartz crystals, much corroded, appear in some thin sections. Zircon and magnetite are accessory minerals.

This quartz-monzonite porphyry which evidently contains considerable soda, is younger than the granite which it cuts in the area four miles west of Alkali Springs and pebbles of it are included in the Siebert lake beds (Miocene).

DIORITE PORPHYRY AND DIORITE

Dikes of diorite porphyry and a few intrusive masses of diorite occur in the Silver Peak, Panamint, Grapevine, and Cactus ranges, the Gold Mountain and Slate ridges and the Bullfrog, Mount Jackson, and Lone Mountain hills. These rocks are hence confined to the western half of the area under consideration. In composition they range from acid diorite approaching granodiorite to a quartz-augite diorite of ophitic texture. Brown hornblende characterizes the more basic types and fragments of serpentine found in the Lone Mountain foothills may be altered forms of still more basic phases.

The diorite-porphyry and diorite are younger than the Paleozoic rocks and the igneous rocks already described, but nowhere were they observed cutting Tertiary lavas. Pebbles occur in the Siebert lake beds (Miocene) and the rock is probably of pre-Tertiary age.

The quartz-monzonite porphyry and the diorite porphyry and diorite, which are the youngest of the pre-Tertiary igneous rocks, occur only in comparatively small masses. They are probably complementary differentiation products of a magma residual from the solidification of the granular siliceous rocks.